北海道大学

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THE INSTITUTE OF LOW TEMPERATURE SCIENCE

HOKKAIDO UNIVERSITY
SAPPORO, JAPAN

1972

Sea ice research laboratory in *Mombetsu*

Snow avalanche research laboratory in *Toikanbetsu*

THE INSTITUTE OF LOW TEMPERATURE SCIENCE HOKKAIDO UNIVERSITY

The Institute of Low Temperature Science of Hokkaido University was established on November 25th, 1941. Its objective was fundamental research into the natural phenomena occurring in Hokkaido's low temperatures.

The institution is greatly indebted to the late Drs. Y. Kon (former president of Hokkaido University), K. Oguma, U. Nakaya, S. Yanagi and S. Ôga for its conception and for the erection in 1935 of its first cold room, where Dr. Nakaya's pioneering studies of artificial snow were carried out.

In August of 1966, an international conference on low temperature science was held at Sapporo, celebrating the twenty-fifth aniversary of establishment of the institute. One hundred and thirty scientists, including fifty two foreigners from ten countries, participated in the conference.

The XI Olympic Winter Games was held in Sapporo in 1972. By request from the organising committee for the Sapporo Olympic, the institute made a comprehensive study of the physical properties of snow and ice best suited for the winter games.

Dr. Oguma was the first director of the institute. The directorate was then transferred, in succession, to Drs. Aoki, Hori, Yosida, Nei, Hori (reappointed), Yosida (reappointed), and the late Dr. H. Ôura (the previous director). The staff now consists of more than ninety members including clerical and technical employees.

Organization

The institute is divided into ten sections: Physics, Applied Physics, Meteorology, Oceanography, Snow Damage, Frost Heaving, Snow Melt, Frost Injury in Plants, Biology and Medicine.

The majority of the research carried out in these sections is naturally concerned with the properties and behavior of substances and organisms at low temperatures. Since the institute is located in Hokkaido where there are much snow and severe cold, it is also the responsibility of

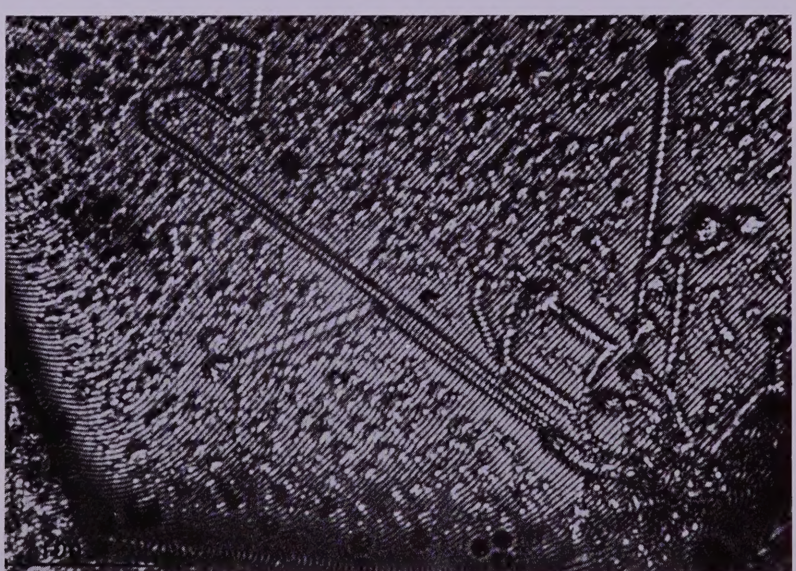
the institute to relate its research to the life and culture of Hokkaido's people as well as to science in general.

The institute have three separate research laboratories, the first for sea-ice research in Mombetsu, the second for avalanche research in Toikanbetsu and the third for frost heaving research in Tomakomai.

Physics Section

This section is concerned with the basic studies on snow and ice. The metamorphism of snow and its transformation process into ice contain very complex phenomena such as sintering, recrystallization, grain growth and vapor transfer within snow texture. These processes have been studied by cinematographically under the isotherm condition, but researches will be continued under the applied stresses and temperature gradients. In relation to these phenomena, changes of internal friction and electrical conductivity of natural and processed snow are being studied as a function of density and age hardening of snow.

In addition, the following basic studies on ice crystals are being carried out from a point of view of solid state physics. The electrical properties of pure and doped single crystal of ice, and growth mechanism of ice from vapor are being studied. Many information on dislocation



Interferogram of etched basal surface of ice. Etch channels created by the dislocation movements rum $10\bar{1}0$ direction.

movement and etching process of ice crystals are being obtained by the cine-microphotographic method.

Applied Physics Section

Physical processes of snow metamorphism has been studied for the past several years both in low land and in high mountain areas in Hokkaido. It was confirmed in a small snow patch named "Yukikabe" (1730 m a. M. S. L.) in Daisetsu Mountain area that the snow of 7 years old has transformed into ice at a depth of 6 m in the patch, and melt-water plays a major role in the transformation from snow into ice. Recently the transition process from snow, firn to glacier ice was also investigated in Alaska. It was found on McCall Glacier in Broocks Range in Arctic Alaska that snow or firn had transformed into glacier ice at a depth of only 1 m in the accumulation area, and the superimposed ice was predominant in the formation of the glacier ice. On Mendenhall Glacier, the behaviour of the melt-water within a glacier body was studied and the water-permeability of the glacier ice mass was measured *in situ.*

Deep core ice samples from Amery Ice Shelf, Wilkes Dome and Cape Folger in Antarctica has been subjected to crystallographic analysis before and after laboratory deformation by a variety of stress condition, in cooperation with University of Melbourne and Antarctic Division of Department of Supply, Australia. Core snow samples from the surface down to 10 m depth collected every 100 km on the route from Showa station to the South Pole by JARE 9, have also been under investigation.

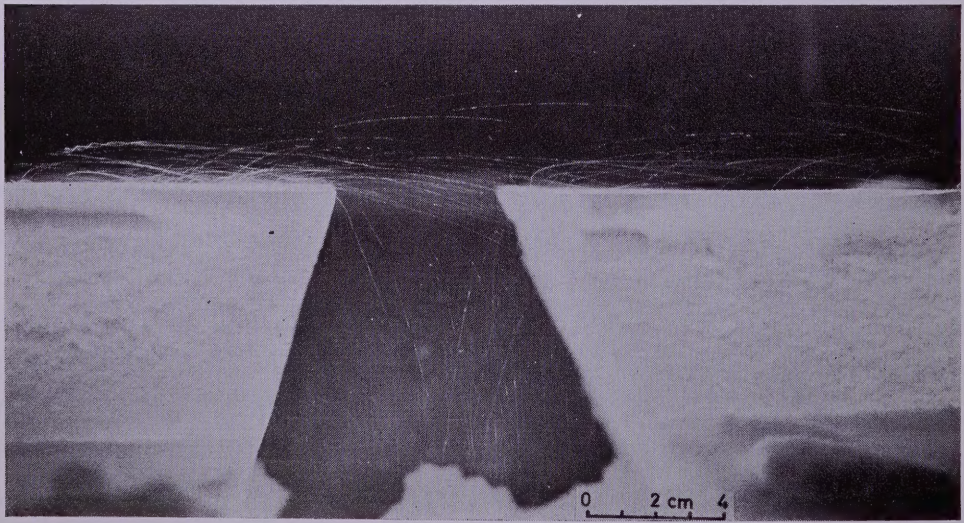
Friction between single crystals of ice and a steel ball has been investigated with reference to the crystallographic orientation and the temperature of ice. Strong anisotropy in friction was found for different crystallographic planes of ice.

Integrated intensity of reflected X-ray from various crystallographic planes of ice was measured by X-ray powder method in the temperature range from $-150°C$ to $-5°C$, and the abnormal reflection was found from (1010) plane between $-60°C$ and $-5°C$. This anomalous reflection was never observed if the powdered ice sample was once annealed.

Meteorology Section

The drop of visibility and the formation of snow drifts during blowing snow are the causes of various incidences such as traffic accidents and mountaineering disasters. Thus basic research on blowing snow is in demand. Heavy blizzards experienced by the members from this section who wintered at the Syowa Base in Antarctica also gave very helpful suggestions in the study of blowing snow. Our special concern has been the generation mechanism of blowing snow. In addition to the observations on natural blowing snow in the field, we are making use of artificial blowing snow created in a wind tunnel in one of the cold rooms. The turbulence in wind has been shown to play an important role in driving the snow particles from the ground snow surface. The trajectories of snow particles have been investigated by high speed movie films or photographs and the bouncing of snow particles, the so-called "saltation", on the ground snow surface has been captured in the films.

Another theme conducted mainly by this section is the glaciological studies extended over a long period in the east Dronning Maud Land in Antarctica. An investigator of our institute has taken part in Japanese Antarctic Research Expedition almost every year for this project. It



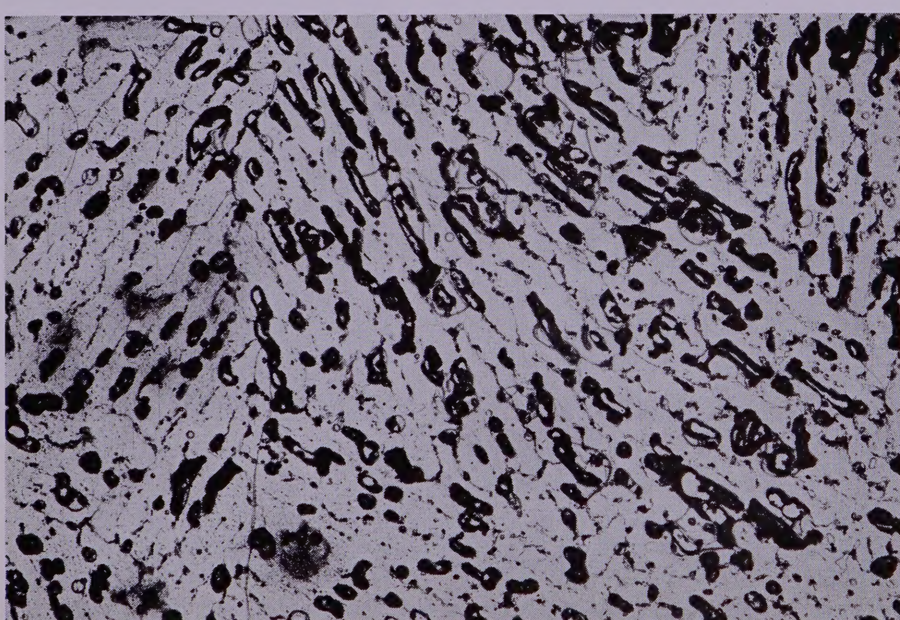
Trajectories of snow particles bouncing along the ground surface and plunging into a snow-trench

aims ultimately at confirming the mass budget of inland ice. The project started from 1968 and will be continued until 1974.

Oceanography Section

The major part of our research in the Oceanography Section is concerned with the nature of sea ice. Basic studies and field observations are being carried out, both in the cold rooms of the institute and on the Okhotsk Sea coast of Hokkaido. Observations and measurements of frazil crystals together with temperature and salinity of the ice cover and the sea beneath, have been made. Our recent research has been denoted to the studies of the temperature dependency of the flexural strength, thermal and electrical properties both in laboratory and in field conditions. The results obtained from the laboratory work are being applied to the natural sea ice under various meteorological conditions.

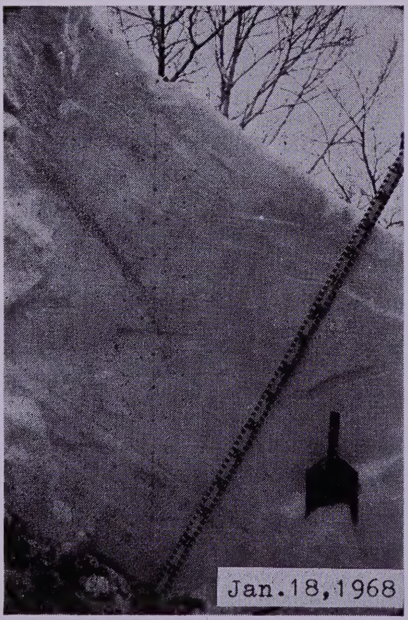
Every winter fishing boats in the seas north of Hokkaido suffer heavy damage and loss from icing. Investigators in this section have developed several effective anti-icing materials in an attempt to reduce this loss. These materials were developed after many direct observations of the icing process at sea and many experiments in the laboratory.

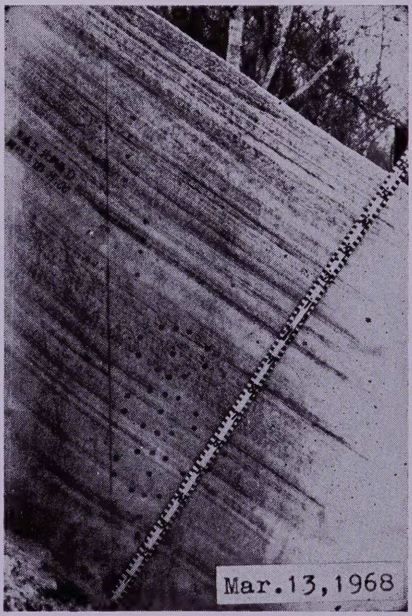


Horizontal section of sea ice (×3)

Snow Damage Section

The snow damage science section was established to study the physical characteristics of snow covers on mountain slopes and the dynamics of snow avalanche. Research work on the internal stress and strain of snow covers on the slopes are being made at Toikanbetsu, northern Hokkaido, where the Avalanche Research Station was built near the observation site. Instruments and methods used in measuring the internal strain of snow cover have been considerably improved. The horizontal hole method was invented in 1967. The creep velocity distribution in the snow cover is obtained from displacements of a number of small holes made in the snow in parallel with the contour of the slope by push rods. Local strain in the snow cover is also obtained by direct observations of a strain ellipse produced by deformation of circularly arranged holes.





Observation of plastic deformation of snow cover on the slope: Fine holes were bored in the snow cover, and their displacement were observed with lapse of time. Circular arrangement of the holes (*left picture*) were deformed into an elliptic arrangement, i.e., strain ellipse (*right picture*) and a vertical line arrangement (*left*) was deformed into a slant curve arrangement (lower half of *right*,) in 55 days. (Holes in the upper half of *right* were bored in the newly deposited snow layer, 13 and 27 days after the first boring respectively)

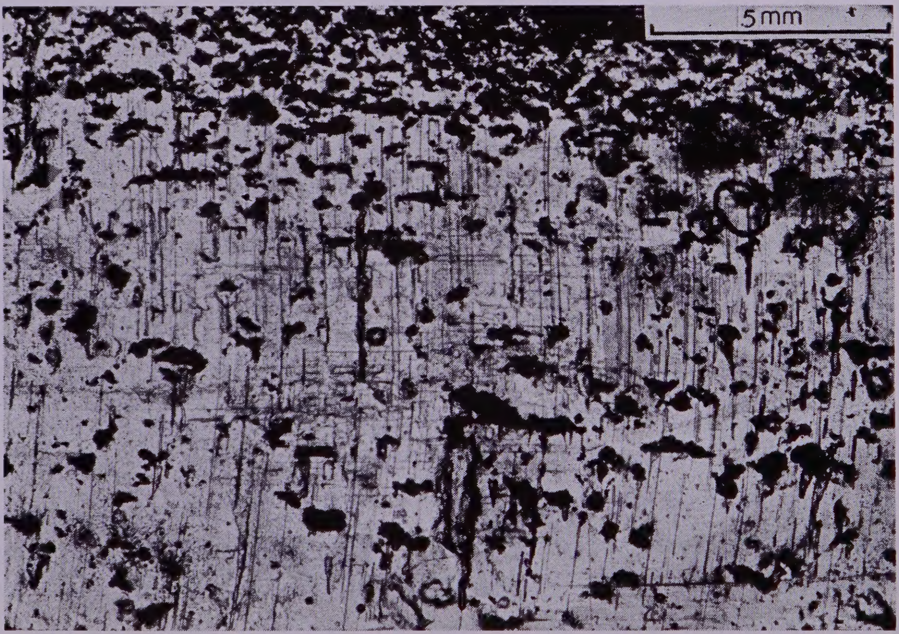
Studies on the growth of depth hoar, the mechanical properties and air permeability of deposited snow have also been carried out both in the field and in the cold room.

Frost Heaving Section

The main objective of this section is the study of basic mechanism of frost heaving encountered in soil freezing.

To date the investigations on the following subjects have been carried out both in the field and in the cold room ; the change of soil moisture content during freezing, the microstructure of frozen soil, the growth process of ice columns (shimobashira) from the soil surface, the heaving force of the frozen ground, and the mechanical properties of the frozen soil.

Recently research has mainly been directed towards the moisture movement through unfrozen soil and its dependence on the soil structure. For this purpose, a water resistant basin filled with frost susceptible soil of known properties has been constructed at Tomakomai, Hokkaido and field experiments under controlled conditions are being carried out. Also,



Vertical Section of ice lens appearing within frozen soil. Black portion, soil ; white portion, ice ; longitudinal line, air bubble

in the laboratory the frost heaving of soil samples are being measured with special reference to crystal structure, the specific surface area and its porosity.

Snow Melt Section

The snow melt research section was established in 1970, to make specific studies on the mechanism of snow melt and various problems related to the melting of snow, which mainly contributes to the supply of water but which at times causes violent floods.

The main subjects of investigations at present are as follows:

1) Heat balance studies for melting snow. Micrometeorological observations are made on snow fields in Sapporo through the winter season and in Moshiri, Hokkaido in April, which gives a typical example of the thawing season in the mountains.

2) Experimental studies of heat transfer between the atmosphere and a melting snow surface. Field work and a series of tests using a temperature regulated wind tunnel are being undertaken.

3) Snow melt run-off in a small drainage area in the mountains. Observations has been made in Moshiri in every melting season in connection to the areal variations of melting rate and heat balance in the area. Special attention has been devoted to the influence of temperature inversion upon snow melt run-off.

Section of Frost Injury in Plant

The primary objective of this section is the studies on resistance and injury against freezing in plants. Plants, in general, show a remarkable seasonal periodicity in freezing resistance. The mechanism of cold acclimation is the primary concern of this section.

Mechanism of survival of plants at super low temperatures has been studied with various plant materials. Freezing storage of less or none hardy plant cells such as tissue culture cells is causing a great concern with reference to the genetic gene storage in liquid nitrogen. Cold climates are prime factor in the natural selection pressure which has led to the evolution of adapted ecotypes and species. Studies on the freezing resistance of woody plants growing in different climates contri-

bute to our understanding of plant adaptation to natural stresses.

Biochemical reactions in plant metabolism governed by temperature have also been a subject of importance to us, because it brings into focus the back-ground material and it provides chemical basis for the understanding of the problematic points in this field.

Plants wintering near the summit of Kurodake (1900 m), Daisetsu Mt.

A cecropia silk worm emerged from a pupa frozen-thawed at and from liquid nitrogen temperature

Biology Section

The purpose of research in this section is to clarify the fundamental mechanisms of life and death in plant and animal at low temperatures.

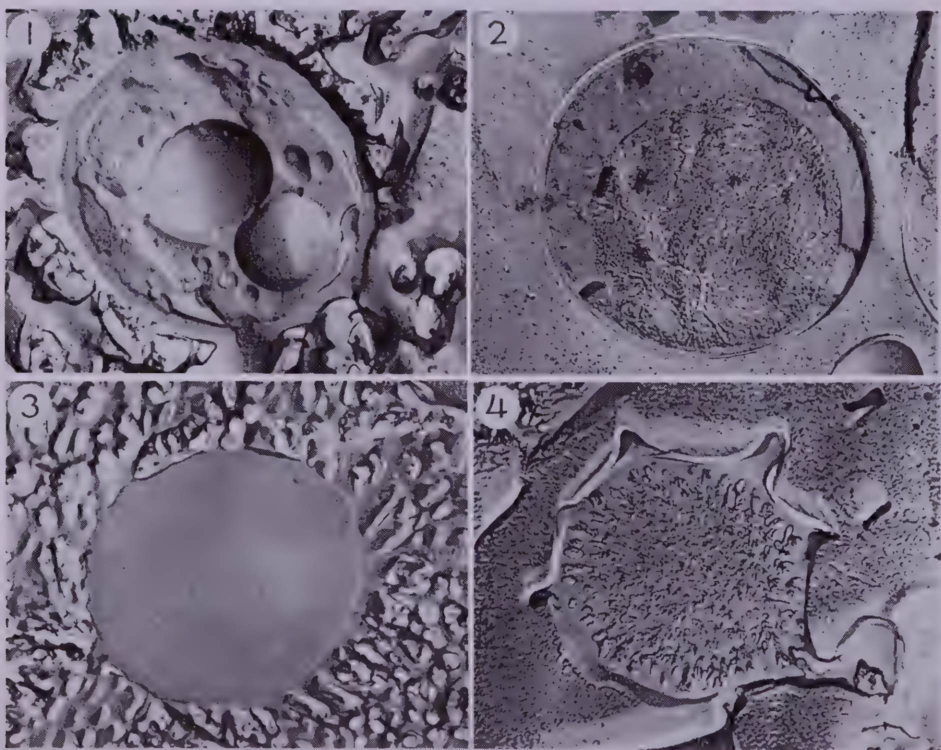
Direct microscopic observations have been made on the freezing process in living tissues and cells of both plant and animal. The results have shown that in various organisms intracellular freezing is usually fatal, while extracellular freezing may be tolerated unless it is too severe or prolonged. Some frost-hardy plants and animals have been observed to survive freezing at extremely low tem-

peratures following antecedent extracellular freezing at temperatures around $-30°C$. One of our recent investigations showed that even intracellular freezing was not always fatal for cells, if the size of ice crystals within the cells was very small in comparison with the wave length of visible light.

Many frost-resistant organisms were found to produce some protective compounds such as polyols and sugars with the approach of the cold season. Our work, however, revealed that mere possession of these compounds was only an additive factor for increasing frost-resistance, and that a formation of a certain protoplasmic condition is prerequisite to exhibit frost-resistance in an overwintering animal.

Medical section

In this section, fundamental studies on the effects of freezing or



Cells in the specimens, frozen very rapidly and freeze-fractured

(1) An yeast cell with 30% glycerol. 10,000× (2) an yeast cell without glycerol. intracellular freezing. 10,000× (3) an erythrocyte with 30% glycerol. 6,000× (4) an erythrocyte without glycerol. intracellular freezing. 6,000×

freeze-drying on biological materials have been made from various points of view.

Microorganisms, protozoa and animal cells such as *E. coli*, yeast, paramecium and red blood cells, and also enzyme proteins are employed as experimental materials. From the results obtained by morphological, biophysical and biochemical investigations, it has been ascertained that most of these materials tend to suffer varying degrees of injuries or changes by freezing or freeze-drying. An emphasis was laid on the aspect that the transfer of water molecules caused by freezing or freeze-drying would affect the biological activities in various systems. In the experiments carried out in the past few years, it was actually clarified that freezing or freeze-drying brought about the destruction of molecular conformation and inactivation of enzymes, such as myosin and catalase, and also the structural alteration of cellular membranes of yeast and erythrocytes and of liver mitochondrial membranes.

Some investigations on cryotechniques, recently developed for electron microscopy, have been made along the same line, in particular, with the freeze-etching method.

Sea Ice Research Laboratory

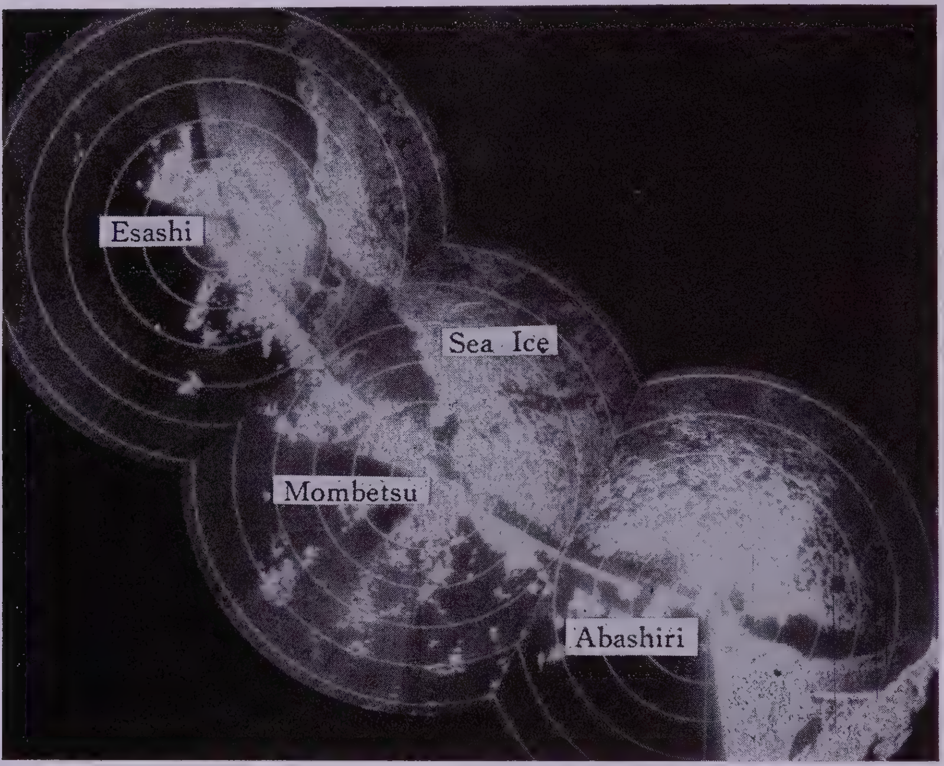
Off the Okhotsk coast of Hokkaido, sea ice forms every winter from the end of December through to the middle of April. The Sea Ice Research Laboratory was established in Mombetsu on the coast in 1965 to further sea ice research which had been carried out by the Institute for more than twenty years.

The Laboratory has a radar system for the sole pourpose of ice observation, the first and the only one in the world, which construction began in 1966 and finished in 1969. Three radar antennas were installed along the coast line *i.e.*, from north to south, on Mt. Tokushibetsu (430 m above sea level) in Esashi, on Mt. Oyama (300 m) in Mombetsu, and at Cape Notoro (200 m) in Abashiri, to cover an area of 60–80 km in width along the entire coast line.

Based on radar information, ice distribution charts in the area are made every day and analysed to give basic data of the movement and deformation of ice field. Several time lapse movies of the radar scope of one frame per five minutes each covering a few days of intensive

ice movement have also been produced, in which the movement of ice shows the appearance of a turbulent flow of viscous fluid.

In addition to the work using the radar system, basic studies on physical properties of sea ice and on the freezing mechanism of sea water have been conducted both in the field and in the laboratory. Concerning the latter study, oceanographic observations along a line north-eastward off Mombetsu are being carried out every month in the ice free season.



Radar echoes from drift ice (Feb. 27. 1970)
Range circles are 5 nautical miles apart

Oversea Field Research

Members of the Institute of Low Temperature Science accomplished or participated in the following four projects in U.S.A., Canada, and U.S.S.R. in 1972.

AIDJEX (Arctic Ice Dynamics Joint Experiment) Pilot Study. March-April.

Arctic Sea Ice Research Expedition. May-June.

Research on Metamorphism of Snow and its Transformation into Glacier Ice in Pacific and Arctic Areas. (A. Japan-U.S. Scientific Cooperative Program). June-August.

Permafrost Survey in Siberia (incl. Forest Ecology). August.

Cold Rooms

In the laboratory building completed in March 1969, there are thirty two cold rooms, which may be divided into four groups, *i.e.* the first floor block, the second floor block, a wind tunnel room with an annex, and a large cold room, their floor areas being 125, 260, 157 and 86 m^2, respectively.

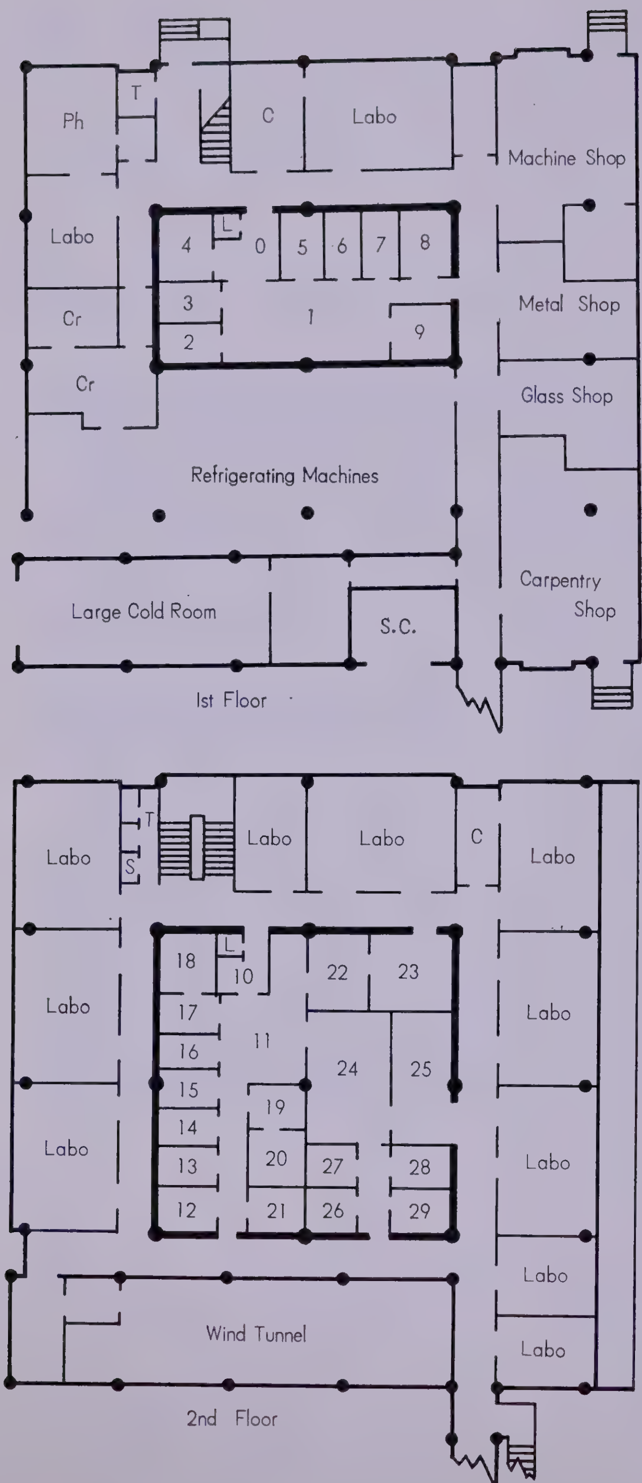
The first floor block consists of an entrance, a common preparatory room (45 m^2), and eight small rooms (each about 8 m^2) equipped with various kinds of testing machines, while the second floor block has an entrance, a common preparatory room (29 m^2), two medium rooms (28 m^2 and 33 m^2), and sixteen small rooms, of which two are installed with an X-ray diffract meter and a micro-beam X-ray apparatus, two are for isotope treatment, and two are for handling poisonous chemicals and are specially designed to meet the necessary safety conditions.

The wind tunnel room has a Göttingen type wind tunnel for studying the drift of snow. The tunnel has a cyclonic collector to prevent drifting snow to recirculate and has an observation space of $50 \times 50 \times 800\ cm^3$. The maximum wind speed is 40 m/s.

Five R 22 freezing machines make $-28°C$ and 48°C brine (trichloroethylene, $CHClCCl_2$), which in turn are circulated through heat exchangers in the rooms to cool them down to $-20°C$ and $-40°C$. An indirect cooling system has been adopted in order to ensure an easy control of room temperatures. Two small rooms on the second floor block have additional booster heat exchangers driven directly by an R 13 freezing machine and can be cooled down to $-60°C$ and $-80°C$, respectively. For the purpose of local cooling, there are brine outlets and inlets in the two medium rooms and the two X-ray rooms.

The room temperatures can be designated at the control panel in the controlling room and can be automatically maintained at $\pm 1°C$ of the assigned temperatures.

The common preparatory rooms, the medium rooms, and the rooms



1st Floor

C	Cold box
Cr	Control room
Labo	Laboratory
Ph	Phytotrone
S. C.	Snow collector for wind tunnel, 2nd floor
T	Toilet
Cold rooms	
0	Entrance
1	Common preparatory room
2-9	Small rooms
L	Lift

2nd Floor

C	Cold box
S	Shower
T	Toilet
Cold rooms	
10	Entrance
11	Common preparatory room
12-16, 21, 26, 27	Small rooms
17, 18	Thin-section process rooms
19	−60°C room
20	−80°C room
22, 23	X-ray rooms
24	Medium room with brine outelts
25	Medium room for refrigerated microscopes
L	Lift

Sketch Map of Cold Room Building

for using poisonous chemicals can be forcibly ventilated with −20°C dry air, while small rooms are ventilated by natural convection through ventilation holes connecting them to the common preparatory rooms.

Table of Freezing Machines

Use	High Stage	Low Stage No. 1	Low Stage No. 2	Deep Freeze
Refrigerant	R 22	R 22	R 22	R 13
Condensing Temperature (°C)	30	—	—	—
Intermediate Pressure Saturated Temp. (°C)	—	−32.5	−32.5	−40
Saturated Suction Temp. (°C)	−35	−55	−50	−93
Refrigerating Capacity (kcal/h)	31,500	23,700	46,500	5,320
(J. R. T.)	9.5	7.2	14.0	1.6
Compressing Power (kW)	26.3	9.26	17.01	19.5
Electric Motor (kW)	30.0	15.0	22.0	22.0
Number	3	1	1	1

Publications

Results obtained by the investigations at the Institute of Low Temperature Science are published in Japanese with English summaries in the journal of "低温科学" (*Teionkagaku*, Low Temperature Science, physics series and biology series) and in English in "Contributions from the Institute of Low Temperature Science" series A (physics and geophysics) and series B (biology and medicine) both edited by the institute. The latest publication was vol. 29 for both the physics series and biology series of the former and series A No. 23 and series B No. 17 for the latter. In addition to these volumes, the proceedings of the international conference on low temperature science in 1966, namely "Physics of Snow and Ice" 1414 pages and "Cellular Injury and Resistance in Freezing Organisms" 257 pages, were published in 1967.

Scientists

(42 in total)

Director : Dr. Éizo ASAHINA

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(2) Applied Physics Section :
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(4) Oceanography Section :
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(6) Frost Heaving Section :
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(8) Section of Frost Injury in Plants :
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(10) Medical Section :
Prof. Dr. Tokio NEI, Ass. Prof. Dr. Hiroshi SOUZU Lecturer Dr. Naofumi HANAFUSA, Assist. Tadashi ARAKI, Tadao MATSUSAKA

(11) Sea Ice Research Laboratory :
Prof. Dr. Tadashi TABATA, Assist. Masaaki AOTA

Educational work

The Institute is open to the post graduate students from various Faculties in Hokkaido University. Master and Doctor courses can be arranged in Physics, Geophysics, Biology and Medicine.

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